Final Report to NASA for

COMPARISON OF CLOUD RESOLVING MODEL SIMULATIONS TO REMOTE SENSING DATA

NAG-1-02008

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August 10, 2005

The purpose of this research was to evaluate the ability of a cloud-resolving model (CRM) to simulate the dynamical, radiative, and microphysical properties of deep convective cloud objects identified using CERES (Clouds and the Earth's Radiant Energy System) on board the Tropical Rainfall Measuring Mission (TRMM) satellite platform, for many cases. A deep convective cloud object is a contiguous region that is composed of satellite footprints that fulfill the following selection criteria: 100% cloud fraction, cloud optical depth > 10, and a cloud top height of at least 10 km. Selection criteria have also been formed for different types of boundary-layer clouds, as described in Xu et al. (2005). The purpose of the cloud object approach is to identify specific areas of where the cloud properties simulated by the CRM systematically differ from the observed cloud properties. Where these systematic differences exist, concrete steps can be made to improve the CRM's simulation of an entire class of clouds, rather than by tuning the model to correctly simulate a single case study, as is often done.

In Eitzen and Xu (2005), a control version of the Advanced Regional Prediction System/Langley Research Center (ARPS/LaRC) model was used to simulate 68 large (effective diameter greater than 300 km) cloud objects identified by CERES over the tropical Pacific Ocean in March 1998. The model is based on ARPS (Xue et al. 2000, 2001). For each of the simulations, the initial state of the model (vertical profiles of wind, temperature, and moisture) was derived from a European Center for Medium-range Weather Forecasts (ECMWF) analysis matched in time and space to the observed cloud objects. To drive the model, combined horizontal and vertical advective tendencies of potential temperature and water vapor mixing ratio were used. These tendencies were obtained from the Colorado State University General Circulation Model. This overall approach is depicted schematically in Figure 1. When making the comparisons between the observations and simulations, probability density functions (PDFs) of cloud properties were used rather than simply comparing their mean values. This was done because the distributions of different cloud properties have different characteristic shapes, and a mean value is generally inadequate to characterize the distribution.

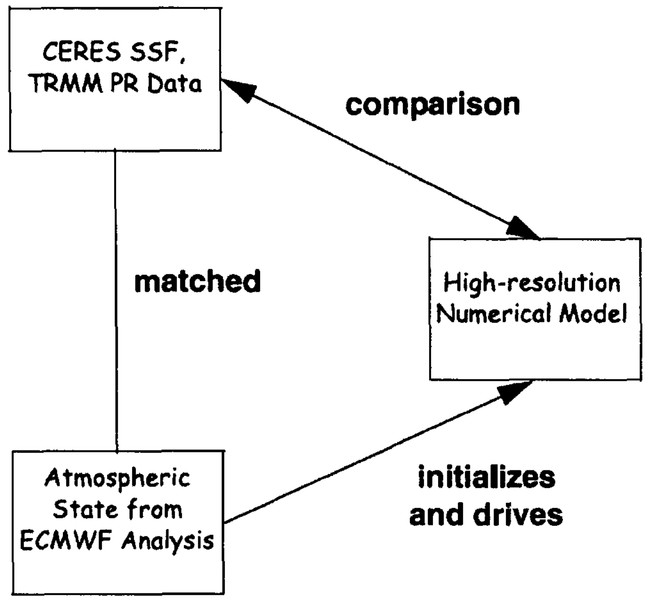


Fig. 1: The approach used in this research project. Taken from Eitzen and Xu (2005).

In order to measure the statistical significance of the differences between PDFs for a given cloud property, a bootstrap approach was used. In this approach, the Euclidean (L2) distance between two PDFs was measured. Then, two randomized PDFs were created by randomly choosing cloud objects from a list that contained the indices of all cloud objects from both of the original PDFs. We choose cloud objects rather than footprints or columns as the independent variable in this approach, because adjacent footprints are highly correlated, whereas each cloud object was observed at a different time and/or place from the other objects. The L2 distances between the randomized PDFs was calculated, and compared to the measured L2 distance. This randomization was repeated 5000 times, and if less than 5% of the L2 distances between the randomized PDFs were greater than the measured L2 distance, then the difference between the two PDFs is said to be significant at the 5% level ($p < 0.05$).

It was found that the control version of the model produced a PDF of albedo that was lower and more strongly peaked than observed, as well as a PDF of cloud top heights that was skewed towards much lower heights than observed. After the control model's Lin et al. (1983) microphysics scheme was modified following Krueger et al. (1995), the model's representation of these quantities improved. This is because the Krueger et al. (1995) modifications tend to increase the prevalence of cloud ice at the expense of snow, creating anvils that are larger and more realistic than those simulated using the original scheme.

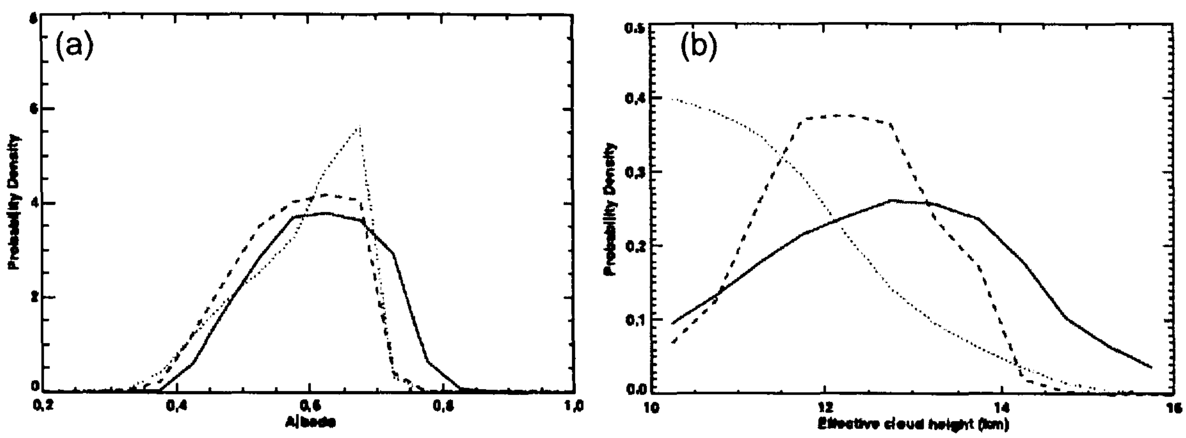
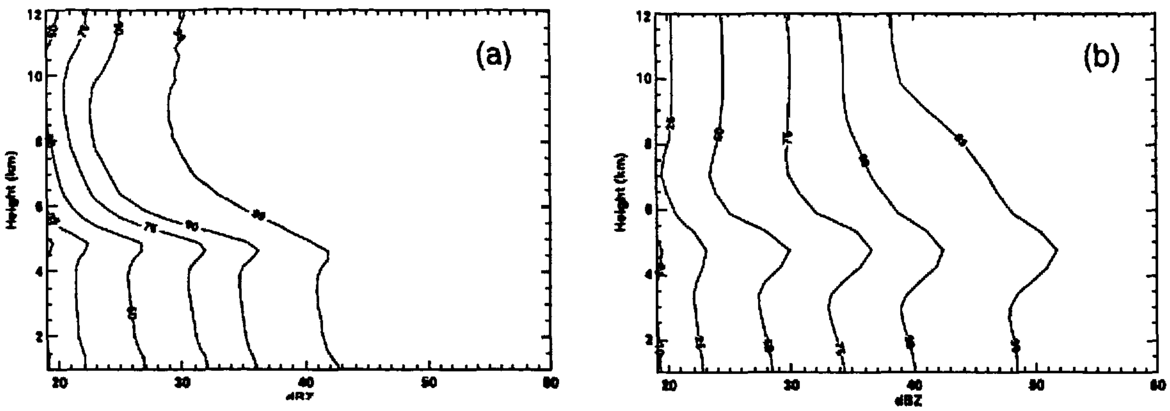


Fig. 2: The PDFs of (a) albedo and (b) cloud top height from CERES observations (solid), the control version of the model (dotted), and the version of the model with new microphysics. (dashed). Taken from Eitzen and Xu (2005).

Since the TRMM Microwave Imager (TMI) and Precipitation Radar (PR) instruments were simultaneously observing the same cloud systems as the CERES instrument, it provided the opportunity for the comparison of simulated precipitation and reflectivity fields between the simulated and observed cloud systems. It was found that the change in microphysics scheme had little impact on the distributions of simulated precipitation rates. These distributions were similar in shape to those observed, although not as skewed towards low precipitation rates as observed. The change in microphysics did have a substantial impact on the simulated reflectivities (see Fig. 3), particularly at high altitudes, where the decrease in snow resulted in a decrease in reflectivity to a more realistic (though still higher than observed) value.



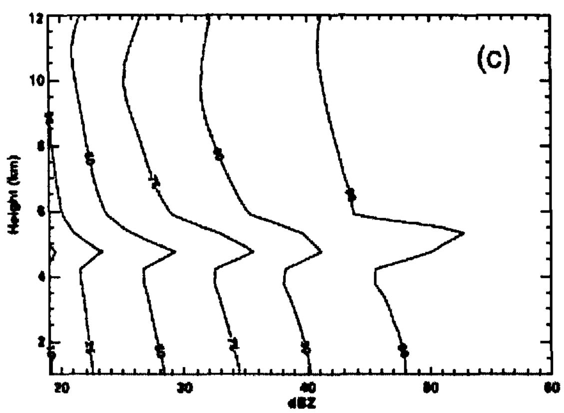


Fig 3: Contoured cumulative density function by altitude diagrams for (a) the observed TRMM PR reflectivities; (b) the reflectivities simulated by the control version of the model; (c) the reflectivities simulated by the model with the new version of the microphysics scheme. Taken from Eitzen and Xu (2005)

Although this research project has focused on modeling, it has also contributed to observational studies (Xu et al. 2005). Our research group has made the cloud object and associated model forcing data used in Eitzen and Xu (2005) publicly available via the Internet: http://cloud-object.larc.nasa.gov. This will allow modeling groups to employ the same iterative process towards model improvement that has been demonstrated in this research project.

References:

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